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## SECTION OF GEOLOGY AND MINERALOGY

### MAY 5, 1947

DOCTOR L. C. GRATON, Laboratory of Mining Geology, Harvard University, Cambridge, Massachusetts: *Nature of Certain Ore-Forming Solutions.*

Among the supergene solutions instrumental in ore production, those which effect the *lateritic* type of concentration, as of Fe, Al, or Ni, through removal of worthless material, chiefly $SiO_2$, are still imperfectly understood. In recent decades, much dependence has been placed on exportation of the $SiO_2$ in colloidal form, either by some direct derivation or from hydrolysis of alkaline silicate. When tested quantitatively in the light of data now available, such processes seem to be of dubious adequacy for the geochemical tasks actually performed.

Hypogene transport of the components of ores, long confronted by consideration of the extremely low water-solubility of the deposited minerals, has likewise been accepted by numerous geologists as accomplished colloidally. The intriguing, though uncommon, phenomenon of concentric banding, urged by Liesegang as indicative of colloidal action, appears to have injected into geological thought a confused interlinking of colloids and diffusion, with unfortunate prejudice to clear understanding of the enormously important geological role of the latter. The rhythmic precipitation represented in "Liesegang rings" is known by the chemists to result from periodic release of supersaturation in

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*electrolyte* solution when the effects of diffusional migration remain undisturbed, and to be in no way *dependent* on colloidal phenomena. Nor does the concentric banding (by many called "colloform"), so commonly seen in mineral occurrence, have other than imperfect and accidental resemblance to the product of rhythmic precipitation revealed in true Liesegang rings.

Replacement is the chief logical stumbling block for colloidal transport, whether in supergene or hypogene processes. Dimension, energy, and mechanism seem to deny to the colloidal units the capacity to accomplish the metasomatic effects commonly seen, whether the scale be that of a tiny fracture-bounded portion within a mineral grain or of a solid mass hundreds of meters on a side. Therefore, even if it were assumed that colloidal transport could account for all deposition in open space, some other means must be invoked for carrying the replacing and displaced components involved in the still greater tonnages represented in replacement. This "other" means could thus suffice for both filling and replacement without any invocation of colloids.

Search, apparently, must continue for an adequate means of moving the mineral-forming components.

DOCTOR ROBERT B. SOSMAN, Research Laboratory, United States Steel Corporation, Kearny, N. J.: *Some Geological Phenomena Observed in an Iron and Steel Plant.**

Because of the large amounts of material used and the high temperatures at which these materials are handled, there are many operations in an iron and steel plant which can be interpreted in terms of the geological processes associated with eruptive rocks.

(1) *Low-pressure absorption of water by a magma, with non-explosive formation of pumice.*—The slag from the iron-smelting blast furnace, with a composition in the vicinity of 35% $SiO_2$, 50% CaO (+ MgO), and 15% $Al_2O_3$, is often granulated with the aid of steam or water. A United States patent issued to Schott in 1934[1] describes a method of granulating such slag by introducing steam from beneath. Development of another such process by W. S. Painter[2] of the United States Steel Corporation led to the discovery that cold water can be introduced beneath such a slag without producing the expected explosions. Further developments showed that a stream of such slag, at about 1400° to 1500° C., flowing down an inclined trough, can be supplied continuously with water entering through fine holes in the bottom of the trough and that it will absorb the water quietly. The slag is still capable of flowing at about 1000° C. At a lower temperature, in the neighborhood of 700 to 800° C., the water is released and the slag swells into a porous sponge, while part of it is converted into a mass of minute glassy hollow spheres, ranging from a few millimeters in diameter down to microscopic size. This mass will flow down an incline by motion of the spheres over one another, lubricated perhaps by interstitial steam or other gases.

A reaction such as this would help to explain the formation of the Valley of Ten Thousand Smokes in Alaska, where a valley ten or fifteen miles long was filled from one side to the other with a flat-topped deposit of pumice from which fumaroles as hot as 650° C. escaped for several years. It also suggests the possibility that an igneous magma, intruding rocks which are saturated with water, may absorb the water

* This address was delivered before the meeting of the Section of Geology and Mineralogy on February 3, 1947.

[1] **Schott, S. W.** U. S. Pat. 1,950,932, Mar. 13, 1934.

[2] Patent has been applied for.

rapidly enough to produce a pressure gradient *toward* the intrusive, instead of surrounding itself with a blanket of outward-driving steam and hot water, as is usually assumed.

(2) *Formation of a batholith in a furnace hearth.*—The liquid metal, an alloy of iron, carbon, silicon, and manganese, at the base of the iron-smelting blast furnace, gradually eats its way downward in the course of several years of continuous operation, into the fireclay brick hearth and even into the concrete foundation beneath, to form a "salamander" sometimes weighing over a thousand tons. The conditions are just the reverse of those of the usual eruptive rock, in that (a) the liquid is *heavier* than the surrounding rock, and (b) the liquid is *above* rather than below. In other respects, the introduction of the salamander resembles that of a batholith. The uniformity of composition of the salamander and the absence of a chilled border phase indicates continuous circulation, which makes it possible, in modern furnaces, to tap the salamander out clean by drilling a drainage opening beneath it. Interesting contact phenomena are observed, such as vugs containing crystalline graphite, corundum, and anorthite, and the conversion of the fireclay brick into a slaty hornstone.

(3) *Laccolithic and stock-like intrusions in a furnace hearth.*—The bottom of the open-hearth furnace for making steel consists of a layer of porous, though consolidated, impure magnesia 8 to 24 inches thick, on top of several courses of uncemented refractory brick. Many such bottoms have been core drilled by R. B. Snow of the Research Laboratory, United States Steel Corporation, in order to observe the changes in constitution of the hearth material. In one such furnace, a layer of steel was found to have spread horizontally as a laccolith between layers of the magnesia.

The liquid steel might normally be expected to run through the bottom of such a furnace like water through a leaky box. This is only prevented by the fact that the steel freezes quickly upon reaching the level in the furnace where the temperature is about 1450 to 1535° C. Under some circumstances, however, it does drill a hole through the bottom of the furnace. Such a "breakout" is nearly always associated with the occurrence of a "boil" in the liquid bath at a point where local circulation has permitted the liquid steel to reach a colder spot and, thus, intensify the release of carbon monoxide from solution in the liquid. Such breakouts are always encouraged by the occasional occurrence of downward penetrating veins of tin, lead, or copper coming

from the steel scrap, though the reason for this effect is not entirely clear. The phenomena, except for the inversion of density and position as noted in case (2) above, are analogous to those observed in the upward penetration of basic rocks, where highly localized vertical intrusion is the rule, and where gases may have been the active agent, as suggested by R. A. Daly.

(4) *Conversion of mechanical energy into heat during flow.*—In the rolling, drawing, and piercing of steel in the mills, it is often observed that the temperature of the metal rises during the operation, even though it is in contact with cold rolls and is being cleaned by jets of water. The phenomena suggest that any plastic material, such as a deeply buried mass of igneous rock, may gradually grow hotter while it is being forced through the interstices of confining rocks, as it is in *lit-par-lit* injection. Such a source for the heat of hot springs was suggested by L. H. Adams in 1924. Geologists have customarily assumed that the heat in a rock has either traveled by conduction and convection from some place at a higher temperature, or has been produced by chemical reactions. The conversion of pressure-volume and gravitational energy into heat by the process of intrusion furnishes another normal source of heat and will explain why many volcanoes extrude lava at a temperature higher than seems consistent with the structures beneath: it has become hotter as it rose to the surface.

(5) *Explosive disruption during cooling.*—The system iron-oxygen has been recently investigated in the Research Laboratory of the United States Steel Corporation because it is fundamental to the phenomenon of "scaling" of steel. It is found that the relation between a liquid oxide of a composition near $Fe_3O_4$, and the crystalline solution between $Fe_3O_4$ and $Fe_2O_3$ that separates when the liquid cools, is a relation of the type known to the physical chemist as "second boiling-point." The crystalline solution dissociates on *cooling*, with the formation of magnetite and gaseous oxygen. This reaction has several times been observed to occur explosively following undercooling of the crystalline solution.[3]

If we imagine a layer of liquid iron oxide and sulfide separating between the siliceous outer shell and the metallic core of the earth, an explosion of the type indicated could result from normal cooling, and

[3] **Darken, L. S., & R. W. Gurry.** J. Am. Chem. Soc. **67**: 1398–1412. 1945; **68**: 798–816. 1946. Mention of the explosive character of the reaction described was inadvertently omitted in the preparation of these two papers.

would be capable of producing the cataclysm postulated by Daly,[4] which resulted in the formation of the moon and its subsequent bombardment by flying fragments to produce the so-called "craters."

[4] **Daly, R. A.** Proc. Am. Philos. Soc. **90**: 104–119. 1946.

## SECTION OF BIOLOGY

### MAY 12, 1947

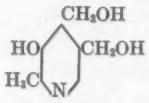
DOCTOR CHARLES W. MUSHETT, MR. ROBERT B. STEBBINS, and MISS MARY N. BARTON, Merck Institute for Therapeutic Research, Rahway, N. J.: *Studies on the Pathologic Effects Produced by Two Analogues of Pyridoxine.** (This lecture was illustrated by lantern slides.)

Although inhibitors and poisons have been used for a long time in the study of isolated enzyme systems, it has been only in relatively recent years that physiological studies have been made with specific metabolite antagonists. Compounds with chemical structures similar to vitamins, hormones, and amino acids have been prepared which antagonize or inhibit such metabolites.[1] The term, *antivitamin*, has been applied to those compounds which counteract the function of vitamins. The inhibition ratio, or the ratio of antivitamin to vitamin that must be present for efficacy, is quite high for most antivitamins. Thus, in the case of pyrithiamine,[2] a thiamine antagonist, a ratio of approximately 40:1 exists; that is, 40 moles of antivitamin are required to counteract the effect of 1 mole of the vitamin. Ott[3] has recently reported that 2,4-dimethyl-3-hydroxy-5-hydroxymethylpyridine (desoxypyridoxine) possesses potent antipyridoxine activity in the chick. This compound has an inhibition ratio of 2:1 and may therefore be considered the most potent of the vitamin B inhibitors yet discovered. Ott has also demonstrated[4] that 2-methyl-3-hydroxy-4-methoxymethyl-5-hydroxymethylpyridine (methoxypyridoxine) is almost as potent an inhibitor of pyridoxine in chicks as is desoxypyridoxine. Methoxypyridoxine has been shown to possess pyridoxine activity in the rat, but no such activity has been observed with desoxypyridoxine.[5] Biochemical studies conducted by Porter, Clark, and Silber[6] reveal that pyridoxine-deficient rats treated with desoxypyridoxine and tryptophane excrete increased quantities of xanthurenic acid and kynurenine. Under comparable conditions, methoxypyridoxine effects a decreased excretion of these metabolic products.

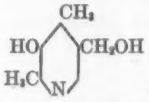
In order to evaluate further the antipyridoxine activity of desoxy-

* This paper was presented by Doctor Mushett.

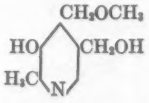
pyridoxine and methoxypyridoxine, it was deemed desirable to study the effects of these compounds from a pathological standpoint. The studies reported here deal primarily with changes produced by these compounds in the lymphoid organs and hematopoietic tissue of several species of laboratory animals. The formulae of the pyridoxine analogues are as follows:




*Pyridoxine*
2-methyl-3-hydroxy-4, 5 *bis* (hydroxymethyl)-pyridine




*Desoxypyridoxine*
2,4-dimethyl-3-hydroxy-5-hydroxymethylpyridine




*Methoxypyridoxine*
2-methyl-3-hydroxy-4-methoxymethyl-5-hydroxymethylpyridine

A fairly constant ratio of spleen weight to body weight existed in chicks maintained on a pyridoxine-deficient diet for two weeks. During the third and fourth weeks, the spleen weight deficit was relatively greater than the body weight deficit. In control chicks on a complete ration, the spleen showed a very great increase in weight relative to the body weight during the third and fourth weeks on test. After four weeks, the spleen weight/body weight ratio in per cent was 0.064 in the case of the deficient birds and 0.234 in the controls. This ratio provides a good estimation of the degree of pyridoxine deficiency in 3–4 weeks old chicks.

The feeding, to chicks, of a diet slightly suboptimal in its pyridoxine content to which was added 50 micrograms of methoxypyridoxine or 100 micrograms of desoxypyridoxine (per 100 gm. diet) resulted in values for spleen weight/body weight ratio which were sig-

nificantly less than the value in chicks receiving the same diet without the addition of these compounds. Indeed, when 200 micrograms of desoxypyridoxine were given under the same conditions, the ratio very closely approached that recorded for chicks fed a pyridoxine-free diet for the same period of time. The histological appearance of the spleens of chicks treated with these compounds and of the pyridoxine-deficient chicks was qualitatively similar. In both instances, the most prominent feature was a hypoplasia or failure of development of lymphoid elements in this organ.

A single subcutaneous injection of 10 mg. per kg. of methoxypyridoxine brought about convulsions and death in young puppies. Puppies maintained on a pyridoxine-deficient diet and given 1 mg. per kg. daily of this analogue died after one to four weeks and showed, upon autopsy, pulmonary edema and dilatation of the right side of the heart. Animals on the same diet which were injected with 5 mg. per kg. of desoxypyridoxine lost weight and died within two months. The pyridoxine-deficient pups showed a progressive decrease in erythrocyte count, hemoglobin, and hematocrit. The resulting anemia was noted clearly to be microcytic and hypochromic in nature within one month. On the other hand, the pyridoxine-treated pups exhibited a gradual increase in these blood values. Pups receiving desoxypyridoxine showed a delayed microcytic anemia, sometimes followed by partial recovery. The blood values of one methoxypyridoxine-dosed pup, which survived for about one month, were only slightly lower than those of the pyridoxine-dosed animals. In this respect, methoxypyridoxine presumably showed some degree of pyridoxine activity. The pups getting desoxypyridoxine as well as those on the pyridoxine-free diet developed leucopenia within a month. This was more marked in the latter group. However, whereas the pyridoxine-deficient pups showed lymphocytosis and neutropenia, the desoxypyridoxine animals showed marked lymphopenia and polynucleosis.

Monkeys which were maintained on a natural stock ration and injected subcutaneously with a large dose of desoxypyridoxine (100 mg. per kg. in two divided doses daily), developed microcytic anemia, leucopenia, and lymphopenia. One animal died in 22 days, the other was sacrificed on the 39th day. Monkeys given 50 mg. per kg. daily for 144 days showed only transient blood changes which resembled those of the first two monkeys.

At autopsy, the most striking change observed in animals treated

with desoxypyridoxine was atrophy of the spleen, thymus, and lymph nodes. The spleen weight/body weight ratios for the dogs and monkeys are shown in TABLE 1. Of interest is the fact that the spleens in

TABLE 1

SPLEEN WEIGHT-BODY WEIGHT RATIOS (EXPRESSED IN PER CENT) IN DESOXYPYRIDINE-TREATED ANIMALS

| Dogs | | Monkeys | | |
|---|---|---|---|---|
| Treated 5 mg./kg. | Controls | Treated 100 mg./kg. | Treated 50 mg./kg. | Controls |
| 0.102<br>0.116 | 0.366<br>0.216 | 0.057<br>0.039 | 0.062<br>0.057 | 0.132<br>0.115<br>0.098<br>0.118 |

the pyridoxine-deficient dogs were relatively increased in size, a finding contrary to that usually observed in pyridoxine-deficient animals. The femoral bone marrow of the monkeys treated with the high dose of desoxypyridoxine was pale yellow in color and gelatinous in consistency. Death in the methoxypyridoxine-treated pups was associated with pulmonary edema and dilatation of the right side of the heart.

Histological sections of the spleen of the monkeys injected with 100 mg. per kg. revealed an extensive loss of lymphoid elements. No germinal centers were present in any of the sections, and remnants of Malpighian follicles were represented by an occasional small accumulation of lymphocytes. Very few lymphocytes remained in the red pulp. As a result of the profound atrophy of the organ, there was an apparent increase in trabecular and reticular tissue. The capsule frequently appeared to be thickened. Many of the central arterioles were very tortuous, due presumably to the shrinking of the spleen as a whole.

Lymph nodes taken from many sites in the body also showed a striking diminution in lymphoid elements, particularly in the follicles. The reticular tissue appeared to be increased in amount, and the demarcation between cortical and medullary portions was indistinct. Marked congestion was evident in the medullary sinuses, and erythrophagocytosis provided a prominent feature.

The blood-forming constituents and fat of the femoral marrow were strikingly reduced. Both erythroid and myeloid elements were affected. Many congested sinusoids were present. Between the small

and widely scattered foci of active hematopoietic cells, a pale, eosinophilic matrix was present, which in some areas appeared relatively homogeneous and in others appeared to be made up of large swollen cells with indistinct cell boundaries.

In the pups treated with desoxypyridoxine, the lymphoid tissue also showed histological evidence of atrophy. The degree of change was comparable to that present in the monkeys given repeated doses of 100 mg. per kg. The thymus showed, in addition to lymphoid hypoplasia, many areas of necrosis. Demarcation between cortex and medulla was frequently indistinct. Hassall's corpuscles were decreased in number and showed morphological abnormalities. Whereas the marrow of the pups on the pyridoxine-deficient diet alone was hyperplastic, the marrow of the pups which were maintained on the pyridoxine-deficient diet and treated with desoxypyridoxine was relatively normal.

Sudan IV stains of the adrenal glands of dogs and monkeys treated with desoxypyridoxine showed a depletion in lipoid content, particularly in the *zona fasciculata* and *zona reticularis*. The adrenal glands of such animals were usually larger than normal. Since lymphoid tissue mass as well as the number of circulating lymphocytes is said to be under the control of adrenal cortical hormones,[7, 8] the question arises as to whether the lymphoid atrophy in desoxypyridoxine-treated animals resulted from a stimulation of the adrenal glands or from a direct action of the vitamin analogue on the lymphoid tissue. Experiments are in progress to study this interesting phenomenon further.

That atrophy of lymphoid organs and of marrow occurs as a result of inanition, has been reported by many investigators.[9] Stoerk[10] has recently demonstrated, however, that in pyridoxine-deficient rats the thymus weight deficit is unduly high with respect to body weight deficit. Treatment of pyridoxine-deficient mice with desoxypyridoxine was found to exaggerate thymic atrophy. Stoerk feels that pyridoxine deficiency plays an apparently specific role in producing lymphoid atrophy.

In addition to the changes in tissues and in the blood already described as effects of desoxypyridoxine treatment, other signs of pyridoxine deficiency were seen in animals given this drug. These include dryness of the hair, scaliness of the skin, tongue lesions, hyperirritability, and epileptiform convulsions. It seems reasonable to assume, therefore, that the lymphoid atrophy observed in animals injected with

desoxypyridoxine is due, primarily, to a state of pyridoxine deficiency induced by this analogue, though it cannot be disputed that inanition also plays a role under these circumstances.

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Doctor Irvin S. Danielson, Lederle Laboratories Division, American Cyanamid Company, Pearl River, N. Y.: *Gas Gangrene.*[*]
(This lecture was illustrated by lantern slides.)

In presenting this brief paper on gas gangrene, it is my purpose to indicate the nature, causative organisms, and incidence of this condition, as well as some published experiences in controlling these infections when once established. I wish to stress, in particular, the present status of the prophylactic immunizing agents developed during the war by a group of investigators working on a co-operative project, both independently and under contract with the Office of Scientific Research and Development.

It is not the purpose, and, in fact, it is impossible, in this brief paper, to review the literature in detail on any single phase of this problem. Nor is it my purpose to give a detailed account of either the production of the immunizing antigens or the methods used in evaluating the efficacy of these agents. I will present sufficient data to indicate the antigenic response that can be expected under the conditions employed.

Many of the data on the antigenic response to these agents are still unpublished. Therefore, a tabulation of the responsible investigators, working in this co-operative group, may be of value at a future date. Table 1 lists their names as well as the institutions in which the work was done.

Gas gangrene is a fulminating infection, generally localized, but producing an intense toxemia. It is usually associated with deep, dirty wounds, and especially wounds where the circulation is embarrassed. True gas gangrene is a myocytis. Generally, the infection is not a single bacterial condition, but rather a condition due to a mixed population of both anaerobes and aerobes. Some of the anaerobes as well as the aerobes, isolated from gas-gangrenous wounds, may be nonpathogenic in pure culture, but may aid in establishing favorable conditions in a contaminated wound so that the pathogenic anaerobic spores may germinate and establish the infection.

The data in table 2, taken from the Medical Research Council Report of 1919, shows the percentage of incidence of some of the

[*] This address was delivered before the meeting of the Section of Biology on January 13, 1947.

TABLE 1

| | |
|---|---|
| Dr. W. A. Altemeier | Cincinnati General Hospital |
| Dr. M. A. Logan | University of Cincinnati |
| Dr. J. Tepper | " |
| Dr. A. A. Tytell | " |
| Mrs. Alice G. Tytell | " |
| Dr. A. A. Weech | " |
| Dr. M. H. Adams | New York University Medical School |
| Dr. A. W. Bernheimer | " |
| Dr. C. M. McLeod | " |
| Dr. Hattie Alexander | The Babies Hospital, New York |
| Dr. D. J. McCune | " |
| Dr. A. H. Dowdy | University of Rochester |
| Dr. H. F. Dowling | George Washington University |
| Dr. B. Robertson | " |
| Dr. Sarah E. Steward | National Institute of Health |
| Dr. W. G. Workman | " |
| Miss F. Clapp | Lederle Laboratories, N.Y. |
| Dr. I. S. Danielson | " |
| Mr. C. H. Parsons | " |
| Dr. Y. SubbaRow | " |
| Mr. A. Webb | " |

anaerobes in gas gangrene cases occurring in the wounded during the first World War.

The high incidence of *Clostridium perfringens* will be noted. Also, the wide variations between the reports of the various observers are obvious. *Cl. sporogenes* and *Cl. fallax*, by themselves, are of doubtful pathogenicity, but may aid in establishing favorable conditions for the multiplication of the pathogenic anaerobes.

TABLE 2

PERCENTAGE INCIDENCE OF ANAEROBES IN GAS GANGRENE M.R.C. REPORT 1919

| Species | Weinberg 91 cases | McIntosh 41 (1914–1918) | McIntosh 52 (1918) | Henry 50 (1918) |
|---|---|---|---|---|
| *Cl. perfringens* (*Cl. welchii*, type A) | 77.0 | 44.0 | 67.0 | 80.0 |
| *Cl. oedematiens* (*Cl. novyi*) | 34.0 | —— | 4.0 | 10.0 |
| *Cl. septicum* (*Vibrion septique*) | 13.0 | 19.5 | 16.0 | 16.0 |
| *Cl. sporogenes* | 27.0 | 36.5 | 39.0 | —— |
| *Cl. fallax* | 26.5 | —— | —— | 6.0 |

TABLE 3, published by MacLennan,[1] shows the incidence of the pathogenic anaerobic bacteria in war wounds occurring in the Middle East during the second World War. The first five organisms are of interest in gas gangrene. The period covered in this report is from

the commencement of hostilities in the Middle East up to, but not including, the second battle of El Alamein. *Clostridium perfringens* still retains a prominent position, with a somewhat lower incidence, however, than the average reported in TABLE 2. In this list, *Cl. histolyticum* and *Cl. bifermentans* are included. The five Clostridii—*perfringens, oedematiens, septicum, histolyticum,* and *bifermentans*—comprise the chief anaerobic bacteria responsible for the condition generally known as gas gangrene.

TABLE 3

PATHOGENIC ANAEROBIC BACTERIA FOUND IN 146 CASES OF GAS GANGRENE: MIDDDLE EAST

(from **J. D. MacLennan**[3])

| Species | Fatal cases | Recovered cases | Fate unknown | Total and percentage |
|---|---|---|---|---|
| *Cl. perfringens* (*Cl. welchii*, type A) | 36 | 35 | 12 | 83 (56) |
| *Cl. oedematiens* (*Cl. novyi*) | 32 | 19 | 4 | 55 (37) |
| *Cl. septicum* (*Vibrion septique*) | 17 | 10 | 2 | 29 (19) |
| *Cl. histolyticum* | 10 | 0 | 0 | 10 (6) |
| *Cl. bifermentans* (*Cl. sordellii*) | 5 | 2 | 0 | 7 (4) |
| *Cl. fallax* | 0 | 2 | 0 | 2 (1) |
| *Cl. tetani* | 10 | 6 | 3 | 19 (13) |
| Streptococci | 6 | 7 | 0 | 13 (9) |

TABLES 2 and 3 give some idea of the incidence of various organisms occurring in gas gangrene. Each study, of course, presents somewhat different figures, but the trend is the same.

The onset of symptoms after wounding may be as short as 7 hours (*perfringens* case reported[2]), or delayed for several weeks. An average figure is generally given as 1 to 2 days, usually under 7 days. Death may follow in the course of hours, or of a few days.

The source of the gas gangrene organisms has long been associated with cultivated soil, especially fecally contaminated soil, since these anaerobes may be found as inhabitants of the intestinal tract of man and animals.

Major MacLennan published a series of articles[1-5] in *The Lancet,* in 1943, 1944, and 1945, describing the gas gangrene problem in relation to the experiences of the British Army in the Middle East and in the Western Desert. In one of these papers,[1] he reports on his study

of the anaerobic flora of 91 samples of soil taken from the Western Desert, ranging from El Daba in the east to Benghazi in the west.

The findings in the samples of sand or sandy soil obtained from the town and agricultural areas differ in no important respect from those published about similar terrain in other parts of the world. The samples from the desert differed very markedly. MacLennan's conclusion is that the untouched desert appears to have an entirely negligible anaerobic flora, and, for practical purposes, may be regarded as being without pathogenic anaerobes. "But what is more noteworthy," he states, "is that the soiled desert also has an extremely limited anaerobic flora, even in sites (such as some Italian camps . . . ) which have been occupied in considerable squalor for several months." This condition exists, due, probably, to the extremely unfavorable conditions of moisture, temperature, and direct sunlight found in the desert. *Clostridium perfringens* survived these conditions for only two weeks in experimentally contaminated soil.

Since, however, approximately one-third of the war wounds[1] in the North African area were contaminated with anaerobes (true gas gangrene developed in only a fraction of those wounded), it was felt, with some supporting evidence, that soiled clothing was the source of infection in the fighting man.

TABLE 4 is a summary of a few sets of published data on the incidence of gas gangrene occurring in the wounded. It will be noted that the incidence varies widely among the groups studied, from 0.33 to 4.5 per cent, with an average incidence of 1.2 per cent. The mortality rate, as reported in the literature, is a very variable figure. At

TABLE 4

INCIDENCE OF GAS GANGRENE IN WOUNDED SUBJECTS

| Author | No. of cases | Number of cases which developed gas gangrene | Percentage of cases which developed gas gangrene |
|---|---|---|---|
| Langley and Winkelstein[7] | 6,000 | 96 | 1.6 |
| Lenner[8] | 750 | 18 | 2.4 |
| MacLennan[5] | 6,800 | 44 | 0.65 |
| Power[9] | 6,000 | 20 | 0.33 |
| Ross and Ryan[10] | 1,815 | 82 | 4.5 |
| *Average Incidence* | | | 1.2% |

best, the overall rate has been high. The following are some published figures:

| | |
|---|---|
| A.E.F. in France, 1918 | 48.15% |
| Millar—civilian cases | 49.7 % |
| MacLennan—in Tripolitania | 30 % |
| Swan—9 cases in Dunkirk | 0 % |
| British Army Report, 83 cases in Dunkirk | 22 % |
| Sachs—San Francisco County Hospital | |
| 1934–37 | 70 % |
| 1937–44 | 43 % |

The mortality rate is greatly influenced by the therapeutic measures taken and the lapse of time between injury and treatment.

It is not my purpose to review the literature on the therapeutic measures used in the treatment of gas gangrene. However, a brief summary of these measures may be of interest. In the case of gas gangrene, as in any other condition where a given course of treatment does not give 100 per cent of the desired results, a multitude of treatments develops. The one factor which is common to all procedures in the treatment of gas gangrene is adequate surgery. The wound is cleaned thoroughly and all necrotic tissue excised. The administration of gas gangrene serum is widely used, both prophylactically and therapeutically. There may be some question as to the value of serum in a well-established case of gas gangrene.[4, 10–12]

Sachs[13] reported favorable results by radiating the affected parts. Many chemotherapeutic agents have been tried both clinically and experimentally with variable results.[14–19] The only antibiotic available during the war for trial on gas gangrene was penicillin; again, results have been variable.

To illustrate the effect of treatment on the outcome of gas gangrene cases, TABLES 5 and 6, from a report published by MacFarlane,[19] are presented.

TABLE 5

GAS GANGRENE OF LEG OR ARM

| Class of treatment | *Penicillin* | | | *No penicillin* | | |
|---|---|---|---|---|---|---|
| | Cases | Deaths | Fatality rate, per cent | Cases | Deaths | Fatality rate, per cent |
| Class I | 23 | 6 | 26.1 | 11 | 1 | 9.1 |
| Class II | 8 | 2 | 25.0 | 30 | 16 | 53.3 |
| Class III | 1 | 1 | 100.0 | 11 | 10 | 90.9 |

TABLE 6

GAS GANGRENE OF THIGH, BUTTOCK, OR SHOULDER

| Class of treatment | *Penicillin* | | | *No penicillin* | | |
|---|---|---|---|---|---|---|
| | Cases | Deaths | Fatality rate, per cent | Cases | Deaths | Fatality rate, per cent |
| Class I | 13 | 5 | 38.5 | 11 | 6 | 54.5 |
| Class II | 8 | 6 | 75.0 | 32 | 26 | 81.3 |
| Class III | 6 | 6 | 100.0 | 31 | 31 | 100.0 |

The cases were divided into three classes, as follows:

Class 1. Treatment within 6 hours of diagnosis, including surgical measures and an initial dose of at least 50,000 units of polyvalent antitoxin, given intravenously.

Class II. Treatment later than 6 hours, or with a smaller dose, or an intramuscular dose of antitoxin.

Class III. No surgical treatment, or no antitoxin.

The cases within a class were further subdivided into those receiving penicillin and those not receiving penicillin. Penicillin treatment consisted of 12,000–15,000 Oxford units every 3 to 4 hours, either intravenous or intramuscular. Practically all patients received sulfonamides in addition to, or instead of, penicillin.

Although the number of cases analyzed is, admittedly, small, there seems to be no doubt as to the value of the combined method of treatment, especially the employment of adequate surgical and antitoxin treatment. The differences between the fatality rate in the penicillin-treated and untreated are not statistically significant, but the trend seems to favor penicillin treatment.

Since the mortality rate in cases of gas gangrene is so high, and since the incidence of gas gangrene in war wounds is sufficiently high to make this condition a serious problem, a group of workers in this country, both independently and under contract with the Office of Scientific Research and Development, set out to develop immunizing agents against the organisms chiefly responsible for gas gangrene. This organized work was started in 1941, and throughout its progress there was a free interchange of data. I propose to present only a small portion of the data collected by this group.

Since all of the five commonly occurring anaerobes (*Clostridium*

*perfringens, oedematiens, septicum, histolyticum,* and *bifermentans*) responsible for the condition known as gas gangrene produce an exotoxin which is antigenic in nature, the first problem was to develop media and techniques which would allow these organisms to produce high concentrations of their respective exotoxins. This work consumed a good deal of time, but was rewarded with a fair degree of success for the three organisms, *Cl. perfringens,*[20, 21] *oedematiens,* and *septicum,*[22] with which we worked.

After developing methods for the production of high-potency toxic filtrate for each organism, the properties of each had to be studied, so that they could be rendered atoxic without too great a loss of their antigenic value. The conversion of the toxins to the corresponding toxoids was accomplished by the standard method of addition of formalin under selected and controlled conditions.

Since *Clostridium perfringens* is so prominent in gas gangrene infections, attention was first directed to the production and testing of toxoids for the protection against infections by this organism. No preparation for the immunization against gas gangrene, that does not contain the antigen of *Cl. perfringens,* could be expected to be of much value, since this organism occurs in from 50 to 80 per cent of all cases of gas gangrene. An effective antigen for the protection against *Cl. perfringens* infection proved to be the most difficult one to obtain, and, as a result, a large amount of data has been collected on this type of preparation.

In the following tables, I shall present some of the antigenicity data obtained with various preparations when administered into various species of animals, including man. Most of these data are recorded as units of antitoxin produced in the blood serum of the various animals. I shall present only the data obtained as a result of the administration of alum-precipitated toxoid. The adjuvant action of alum on these toxoids is just as marked as it is with other toxoids.

In judging these data, we feel that a serum antibody level of more than 0.1 unit per ml. will afford protection against a reasonable live-culture or toxin challenge. TABLE 10 presents data obtained by Drs. Dowdy and Logan which helped to fix this level in our minds.

TABLES 7, 8, 9, 11, and 12, have the same general arrangement. An explanation of TABLE 8 will serve to illustrate all. In the left column, the intervals used in the titration of the serum are listed. In

the spaces to the right of this column are listed the numbers of animals whose sera titrated within the range indicated. The box headings should be interpreted in the following manner: "Dose = 1 ml. s.c." means that each dose listed under this heading is 1 ml. subcutaneously injected. Columns headed "1 dose" indicate only one dose given; "2 dose" indicates 2 doses given. The number of days given above the number of doses indicates the interval between this dose and the previous one. The number of days under the number of doses gives the time elapsing between the last dose and the test bleeding. The bottom line gives the titration value of a pooled sample of sera from all the animals within a group. Above each set of data is given the name of the person responsible for the data (refer to TABLE 1).

TABLE 7 presents data on the *perfringens* antibody response elicited in guinea pigs by the injection of 1 and 2 doses of a *perfringens-oedematiens* toxoid. This work was done in three different laboratories testing the same preparation. A close agreement between the different laboratories is to be noted, although different intervals of time were used for the immunization schedule.

TABLE 7

*Perfringens* ANTIBODY RESPONSE TO INJECTION OF BIVALENT TOXOID (*perfringens-oedematiens*), ALUM-PRECIPITATED: GUINEA PIGS

| Author | Logan | | Clapp | | M. Adams | |
|---|---|---|---|---|---|---|
| Units antibody per ml. serum | Dose = 1 ml., s.c. | | Dose = 1 ml., s.c. | | Dose = 1 ml., s.c. | |
| | 1 dose | 14 days 2 dose 14 days | 1 dose 6 weeks | 28 days 2 dose 14 days | 1 dose 24 days | 1 dose 46 days |
| 0.05 | | | | | | 1 |
| 0.05–0.1 | | 3 | | | | |
| 0.1 –0.2 | | | 6 pooled | | 2 | 1 |
| 0.2 –0.5 | | 2 | | | | 4 |
| 0.5 –1.0 | | 2 | | 6 pooled | | |
| 1.0 –2.0 | | | | | 5 | 1. |
| 2.0 –5.0 | | 2 | | | | |

TABLE 8 presents data obtained by Mr. Webb using the same bivalent toxoid used as in TABLE 7. In this table, the comparison between the size of the immunizing dose and the number of doses is well illustrated. As good, if not better, an antibody response was produced by 0.12 ml. of toxoid administered in three divided doses, as with 2.0 ml. administered in two doses.

TABLE 8

*Perfringens* ANTIBODY RESPONSE TO INJECTION OF BIVALENT TOXOID (*perfringens-oedematiens*), ALUM-PRECIPITATED: GUINEA PIGS (Webb)

| Units antibody per ml. serum | Dose = 1 ml., s.c. | | | Dose = 0.2 ml., s.c. | | | Dose = 0.04 ml., s.c. | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 dose 21 days | 21 days 2 dose 21 days | 21 days 3 dose 21 days | 1 dose 21 days | 21 days 2 dose 21 days | 21 days 3 dose 21 days | 1 dose 21 days | 21 days 2 dose 21 days | 21 days 3 dose 21 days |
| 0.0 –0.05 | 8 | | | 6 | | | 9 | 6 | |
| 0.05–0.1 | 2 | | | 2 | 2 | | | 1 | 2 |
| 0.1 –0.2 | | 6 | | | 1 | | | | 2 |
| 0.2 –0.5 | | 2 | 1 | | 1 | 2 | | 1 | 1 |
| 0.5 –1.0 | | 1 | 5 | | 2 | 1 | | 1 | 2 |
| 1.0 –2.0 | | 1 | 3 | | | | | | 1 |
| 2.0 –5.0 | | | | | | 2 | | | 1 |
| 5.0 –10.0 | | | 1 | | | 1 | | | 1 |
| *Pool value, Units* | | 0.2–0.5 | 1.0–2.0 | 0.0–0.05 | 0.2–0.5 | 2.0–5.0 | | 0.1–0.2 | 0.5–1.0 |

TABLE 9 presents the serum antibody titers obtained in rabbits which had been immunized with either monovalent *perfringens* toxoid or bivalent *perfringens-oedematiens* toxoid. The rabbit responds somewhat better to these toxoids than does the guinea pig. It will be noted that the immune responses to monovalent and bivalent toxoids are equivalent, indicating that no interference has occurred.

TABLE 9

ANTIBODY RESPONSE TO INJECTION OF *perfringens* TOXOIDS, ALUM-PRECIPITATED: RABBITS (Logan)

| Units antibody per ml. serum | (Monovalent) Dose = 1 ml., s.c. | | (Bivalent) Dose = 1 ml., s.c. | | (Bivalent) Dose = 1 ml., s.c. | |
|---|---|---|---|---|---|---|
| | 1 dose 28 days | 28 days 2 dose 14 days | 1 dose 28 days | 28 days 2 dose 14 days | 1 dose 28 days | 28 days 2 dose 14 days |
| 0.0 –0.05 | | | | | | |
| 0.05–0.1 | 2 | | 1 | | 3 | |
| 0.1 –0.2 | 5 | | 7 | | 7 | 1 |
| 0.2 –0.5 | 2 | 2 | 1 | | | 1 |
| 0.5 –1.0 | | 5 | | 5 | | 5 |
| 1.0 –2.0 | | 2 | | 4 | | 1 |
| *Pool, units* | 0.1–0.2 | 0.5–1.0 | 0.1–0.2 | 0.5–1.0 | 0.1± | 0.5–1.0 |

TABLE 10 is a summary of the data obtained by Dr. Dowdy in his study involving dogs. In this study, a single dose of *perfringens* toxoid was administered. Sixty-nine per cent of the dogs responded with a blood serum titer greater than 0.1 unit per ml. Twenty-one days after the administration of the toxoid, these dogs were given a live-culture challenge of such magnitude that over 90 per cent of the control dogs developed gas gangrene and died with typical symptoms.

In the group of 23 dogs having a serum titer of less than 0.1 unit per ml. of serum, only 43.5 per cent survived the live-culture challenge dose, while 49 out of 51 animals (96 per cent), having a serum titer greater than 0.1 unit, survived. One of these two dogs that died had a titer in the range of 2.0 to 5.0 units per ml.

These data, as well as other data using guinea pigs, influenced us in considering that 0.1 unit of antibody per ml. of serum should be a satisfactory minimal response to be acceptable for human subjects.

TABLE 11 presents some of the data, obtained by various workers, on the antigenic response produced in guinea pigs by the administration of *oedematiens* toxoid. The antigen used in these tests was a

TABLE 10

RESPONSE OF DOGS TO *perfringens* TOXOID*, ALUM-PRECIPITATED: Lb = 18
The dogs were given a single dose of .1 ml. subcutaneously. They were bled in 21 days and challenged with culture injected intramuscularly.

| Number of dogs immunized | *Number of dogs showing titers indicated below immediately before the culture challenge* | | | | | | |
|---|---|---|---|---|---|---|---|
| | Units of antitoxin/ml. serum | | | | | | Number surviving at least 10 days |
| | 0.0 to 0.1 | 0.1 to 0.2 | 0.2 to 0.5 | 0.5 to 1.0 | 1.0 to 2.0 | 2.0 to 5.0 | |
| 74 | 23 | 16 | 13 | 6 | 9 | 7 | |
| Survivors at each level | 10 | 15 | 13 | 6 | 9 | 6 | 59 |
| Per cent survival | 43.5 | 94 | 100 | 100 | 100 | 86 | |
| *Total per cent survival* | | | | | | | 80 |

*Control dogs*

16 dogs† Total survival = 1 = 6.25%

* This work was done through cooperation with the laboratories of Dr. Andrew H. Dowdy, Strong Memorial Hospital, Rochester, N.Y. Serum of the dogs was sent to the Cincinnati laboratory for alpha-antitoxin analysis. Immunization and challenge of the dogs was carried out at Rochester.

† The titers of 10 control dog sera were tested previous to challenge. Four of these dogs had "titers" = 0.1–0.2 units. They did not survive challenge. Of the 74 experimental dogs, 12 had pre-immunization "titers" ranging from 0.05 to 0.2 units. These dogs showed an appreciable increase in titers after toxoid treatment and survived the challenge.

TABLE 11

*Oedematiens* ANTIBODY RESPONSE TO INJECTION OF BIVALENT TOXOID (*perfringens-oedematiens*) ALUM-PRECIPITATED: GUINEA PIGS

| Author | Logan | Clapp | Clapp | Adams |
|---|---|---|---|---|
| | Dose = 1 ml., s.c. | Dose = 1 ml., s.c. | Dose = 1 ml., s.c. | Dose = 1 ml., s.c. |
| Units antibody/ml. serum | 2 dose | 1 dose 6 weeks | 4 weeks 2 dose 2 weeks | 1 dose 45 days |
| 0.1 | | | | |
| 0.1–0.2 | | | | 1 |
| 0.2–0.5 | | | | 1 |
| 0.5–1.0 | 1 | | | 1 |
| 1.0–2.0 | | 6 pooled | | 3 |
| 2.0–5.0 | 5 | | | 1 |
| 5.0–10.0 | 2 | | | |
| 10 | 1 | | 6 pooled | |
| 25–50 | | | | |

bivalent mixture of *oedematiens* and *perfringens* toxoids. The data from the mixtures are important in that each antigen must function in the presence of the other. These results show that the *oedematiens* toxoid does provoke a good response in guinea pigs even after the administration of only one dose.

Similar data are presented in TABLE 12 on the response which the bivalent toxoids (*oedematiens-perfringens*) produced in guinea pigs when graded doses (1.0 ml., 0.5 ml., and 0.25 ml.) were subcutaneously administered. Again, it is evident that this antigen is very effective in producing a good antibody titer of blood serum in guinea pigs.

The third member of this group of antigens studied was the toxoid produced from the exotoxin of *Clostridium septicum*. TABLE 13 presents data on the antibody titer of blood serum obtained in guinea pigs following the subcutaneous administration of doses of various sizes. The unitage recorded was obtained on pools of serum taken from 6 to 10 animals. It is evident, from these data, that the guinea pig responds well to the subcutaneous injection of this toxoid. Two injections of only 0.1 ml. of toxoid produced, within a period of one month, serum titers of 1.0 to 2.0 units per ml.

Throughout this discussion, nothing has been said as to potencies of the various toxoids as measured by combining values, or toxic properties of the original material. It is not my purpose to discuss the various methods of evaluating these preparations or to present data on the antigenic response to preparations of various potencies as measured by these other methods. The antigenic data reported here were obtained with preparations having, per immunizing dose, the following values: *perfringens* toxoid equivalent to 15 to 18 Lb; *oedematiens* toxoid formed from 60 to 70 test doses of toxin; *septicum* toxoid formed from 4 to 5 L+ doses of toxin. Toxoids having similar potencies and, in many cases, the identical preparations, were tested on human subjects in a number of laboratories, all of which are included in TABLE 1.

The ultimate goal of this work was to produce a polyvalent antigen which will be capable of protecting human subjects from developing gas gangrene infections. Therefore, a great deal of interest is attached to the antigenic data recorded in the next four tables and three figures. A more detailed discussion of the methods and procedures followed can be found in a recent publication by Tytell, Logan, Tytell, and Tepper.[23]

TABLES 14 to 17 were arranged by Dr. M. A. Logan. The toxoids

TABLE 12

*Oedematiens* ANTIBODY RESPONSE TO INJECTION OF BIVALENT TOXOID (*perfringens-oedematiens*), ALUM-PRECIPITATED: GUINEA PIGS

| Author | Webb | | | Webb | | | Webb | | |
|---|---|---|---|---|---|---|---|---|---|
| Units antibody/ml. serum | Dose = 1 ml., s.c. | | | Dose = 0.5 ml., s.c. | | | Dose = 0.25 ml., s.c. | | |
| | 1 dose 3 weeks | 3 weeks 2 dose 3 weeks | 3 weeks 3 dose 3 weeks | 1 dose 3 weeks | 3 weeks 2 dose 3 weeks | 3 weeks 3 doses 3 weeks | 1 dose 3 weeks | 3 weeks 2 dose 3 weeks | 3 weeks 3 dose 3 weeks |
| 0.1 | | | | 1 | | | 1 | | |
| 0.1–0.2 | | | | | | | 2 | | |
| 0.2–0.5 | 10 pooled | | | 3 | | | 5 | | |
| 0.5–1.0 | | | | 4 | | | | | |
| 1.0–2.0 | | | | 2 | | | 2 | | |
| 2.0–5.0 | | | | | | | | | |
| 5.0–10.0 | | | | | | | | 10 pooled | |
| 10 | | 10 pooled | | | 10 pooled | | | | 10 pooled |
| 25–50 | | | 10 pooled | | | 10 pooled | | | |

TABLE 13

ANTIBODY RESPONSE TO INJECTION OF *Cl. septicum* TOXOID, ALUM-PRECIPITATED: GUINEA PIGS (Webb)

| ml. of Antigen per dose, s.c. | | *Serum antibody titers of pooled bloods units per ml.* | | | | Remarks |
|---|---|---|---|---|---|---|
| | | 1 dose | No. in pool | 2 dose | No. in pool | |
| 1. | 1.0 | 0.5–1.0 | 10 | 4.0–8.0 | 10 | Dose given as fraction of ml.; 2-week interval |
| | 0.5 | 0.2–0.4 | 10 | 4.0–8.0 | 9 | |
| | 0.2 | 0.2 | 10 | 2.0–4.0 | 8 | |
| | 0.1 | 0.1 | 10 | 1.0–2.0 | 8 | |
| 2. | 0.5 | 0.5–1.0 | 10 | 4.0–8.0 | 10 | Dose brought up to 1 ml. with alum-precipitated medium; 2-week interval |
| | 0.2 | 0.2 | 10 | 4.0 | 10 | |
| | 0.1 | 0.1 | 9 | 1.0–2.0 | 6 | |
| 3. | 1.0 | 1.0–2.0 | 8 | | | 3-week interval |
| | 0.5 | 2.0–4.0 | 10 | | | |
| | 0.2 | 0.8 | 10 | | | |
| | 0.1 | 0.2–0.4 | 10 | | | |

were administered subcutaneously in 1 ml. doses. The data in these tables show the serum antibody response to 1, 2, and 3 doses, given at various intervals of time. The number of subjects that had blood serum titers within a given range are recorded in the tables under the headings of these values. The values given in the column "Percentage in 'protective range'" are based on the assumption that 0.1 unit, or more, of antibody per ml. of serum would confer protection on a human subject receiving a field infection. At the present time, no one can state what this value is, if such a value can ever be given. It is possible that a lower level of circulating antibody might protect the majority of subjects receiving a field infection. On the other hand, there is a possibility that the human subject may require a higher concentration of circulating antibody than does the dog or guinea pig, to afford good protection against these infections. At the bottom of each table is tabulated the "Percentage of positive response" to each dose. This value indicates the percentage of individuals whose blood serum contained sufficient antibody to be measurable, which, in the case of *perfringens,* is about 0.05 unit per ml. From TABLE 14, it is seen that only two subjects out of twenty produced a measurable quantity of antibody following administration of one dose. After two doses, 60 per cent had measurable antibody in their blood serum, with only 35

per cent reaching the "protective range." After a third dose of toxoid, administered six weeks after the second dose, 85 per cent of the subjects had measurable antibody titers, with 50 per cent in the "protective range."

TABLE 14

ALPHA ANTITOXIN RESPONSE TO *perfringens* TOXOIDS, ALUM-PRECIPITATED: HUMAN SUBJECTS (Logan)

Toxoid—Lb 15

Two doses given at 4 week intervals and *a third dose at six weeks after second dose.*

| | Units antitoxin/ml. serum | | | | | Percentage in "protective range" |
|---|---|---|---|---|---|---|
| | 0 to 0.05 | 0.05 to 0.1 | 0.1 to 0.2 | 0.2 to 0.5 | 0.5 to 1.0 | |
| Previous to immunization | 20 | — | — | — | — | |
| 4 weeks after first dose | 18 | 2 | — | — | — | |
| 6 weeks after second dose | 8 | 5 (25%) | 7 (35%) | — | — | 35 |
| 4 days after third dose | 9 | 6 (30%) | 4 (20%) | 1 (5%) | — | 25 |
| 7 days after third dose | 7 | 4 (20%) | 3 (15%) | 6 (30%) | — | 45 |
| 14 days after third dose | 3 | 7 (35%) | 4 (20%) | 3 (15%) | 3 (15%) | 50 |

Percentage of positive response 1 dose = 10%;
Percentage of positive response 2 doses = 55%;
Percentage of positive response 3 doses = 85%.

TABLE 15 presents data of the same nature as TABLE 14, with the exception that the third dose of toxoid was administered 12 weeks after the second dose. Within this group, 88 per cent of the subjects developed measurable antibody titers, while 80 per cent reached a level in the "protective range" two weeks after the administration of the third dose.

TABLE 16 presents similar data, with the exception that the third dose was administered 16 weeks after the second dose. In this group, 100 per cent of the subjects developed measurable antibody titers, while 88 per cent reached a level in the "protective range" two and three weeks after receiving the third dose.

TABLE 17 presents similar data, with the exception that the third dose was administered 40 weeks after the second dose. In this group, 100 per cent of the subjects had serum antibody titers within the "pro-

TABLE 15

ALPHA ANTITOXIN RESPONSE TO *perfringens* TOXOIDS, ALUM-PRECIPITATED: HUMAN SUBJECTS (Logan)

Toxoid—Lb 15

Two doses given at 4 week intervals and *a third dose given at 12 weeks after the second dose.*

| | Units antitoxin/ml. serum | | | | | | | | Percentage in "protective range" |
|---|---|---|---|---|---|---|---|---|---|
| | 0 to 0.05 | 0.05 to 0.1 | 0.1 to 0.2 | 0.2 to 0.5 | 0.5 to 1.0 | 1.0 to 2.0 | 2.0 to 5.0 | 5.0 to 10.0 | |
| Previous to immunization | 25 | — | — | — | — | — | — | — | |
| 4 weeks after first dose | 23 | 2 | — | — | — | — | — | — | 0 |
| 3 weeks after second dose | 12 | 4 | 3 | 6 | — | — | — | — | 36 |
| 7 weeks after second dose | 13 | 3 | 6 | 3 | — | — | — | — | 36 |
| 12 weeks after second dose | 18 | 4 | — | 3 | — | — | — | — | 12 |
| 1 week after third dose | 7 | 4 | 4 | 6 | 1 | 2 | 1 | — | 56 |
| 2 weeks after third dose | 3 | 2 | 2 | 4 | 7 | 4 | 2 | 1 | 80 |
| 8 weeks after third dose | 7 | 2 | 5 | 5 | 4 | 1 | 1 | — | 64 |

Percentage of positive response 1 dose = 8%;
Percentage of positive response 2 doses = 52%;
Percentage of positive response 3 doses = 88%.

tective range" two weeks after the administration of the third dose of toxoid. Sixty-eight per cent of the subjects were still within the "protective range" 40 weeks after the administration of the third dose.

From the response recorded in TABLES 14–17, it seems reasonable to assume that, with an active program of immunization, giving booster injections at 6- to 12-month intervals, a relatively high serum antibody titer would be maintained.

FIGURE 1 summarizes the serum antibody titers for alpha antitoxin for *perfringens* determined in 125 human subjects two to three weeks after receiving a third dose of toxoid containing *perfringens* toxoid. This graph includes data obtained in four laboratories. The basic immunizing antigen varied six-fold in combining potency; *i.e.*, from Lb 3 to 18, and the interval between the second and third doses varied from 42 days to one year. The data include the response obtained from the administration of monovalent *perfringens*, bivalent *perfringens-oedematiens*, and trivalent *perfringens-oedematiens-septicum* toxoids.

TABLE 16

ALPHA ANTITOXIN RESPONSE TO *perfringens* TOXOID, ALUM-PRECIPITATED: HUMAN SUBJECTS (Logan)

Toxoid—Lb 15

Two doses given at 4 week intervals with *a third dose given at 16 weeks.*

| | Units antitoxin/ml. serum | | | | | | | Percentage in "protective range" |
|---|---|---|---|---|---|---|---|---|
| | 0 to 0.05 | 0.05 to 0.1 | 0.1 to 0.2 | 0.2 to 0.5 | 0.5 to 1.0 | 1.0 to 2.0 | 2.0 to 5.0 | |
| Previous to immunization | 9 | — | — | — | — | — | — | 0 |
| 4 weeks after one dose | 9 | — | — | — | — | — | — | 0 |
| 3 weeks after second dose | 6 | 1 | — | 2 | — | — | — | 22 |
| 16 weeks after second dose | 8 | 1 | — | — | — | — | — | 0 |
| 1 week after third dose | 1 | 1 | 2 | 4 | — | 1 | — | 77 |
| 2 weeks after third dose | — | 1 | 1 | 1 | 4 | 1 | 4 | 88 |
| 3 weeks after third dose | — | 1 | 1 | 1 | 2 | 3 | 2 | 88 |

Percentage of positive response 1 dose = 0%;
Percentage of positive response 2 doses = 33%;
Percentage of positive response 3 doses = 100%.

No differences could be noted in the response to any of the three types of preparations. These data show that 89 per cent of the subjects had antibody titers in the "protective range."

FIGURE 2 gives a distribution diagram of the blood serum titers obtained on 82 human subjects receiving three 1 ml. doses of toxoid preparations containing *oedematiens* toxoid. Some of these subjects received monovalent toxoid, others bivalent, containing *perfringens* and *oedematients* toxoids; and still others received the trivalent mixture containing the antigens for *perfringens, oedematiens,* and *septicum.* The third dose was given at any time from 35 days to 14 months after the second dose. We feel that all the subjects represented in this graph reached an antitoxin titer in the "protective range."

FIGURE 3 gives a distribution diagram of the blood serum titers of subjects receiving three doses of toxoid containing *Clostridium septicum* toxoid. These subjects received the trivalent mixture containing toxoids for *perfringens, oedematiens,* and *septicum* for all three doses administered. The third dose was given 1 year after the second dose. The number of subjects is small and, therefore, the distribution curve

TABLE 17

ALPHA ANTITOXIN RESPONSE TO *perfringens* TOXOIDS, ALUM-PRECIPITATED: HUMAN SUBJECTS (Logan)

Toxoid—Lb 18

Two doses given at 4 week intervals with *a third dose at 40 weeks after the second dose.*

| | Units antitoxin/ml. serum | | | | | | | Percentage in "protective range" |
|---|---|---|---|---|---|---|---|---|
| | 0 to 0.05 | 0.05 to 0.1 | 0.1 to 0.2 | 0.2 to 0.5 | 0.5 to 1.0 | 1.0 to 2.0 | 2.0 to 5.0 | |
| Previous to immunization | 38 | — | — | — | — | — | — | |
| 4 weeks after first dose | 33 | 4 | 1 | — | — | — | — | 2.6 |
| 3 weeks after second dose | 3 | 12 | 13 | 6 | 4 | — | — | 60.0 |
| 28 weeks after second dose* | 27 | — | — | — | — | — | — | 0.0 |
| 40 weeks after second dose | 27 | — | — | — | — | — | — | 0.0 |
| 2 weeks after third dose† | — | — | 4 | 8 | 8 | 4 | 2 | 100.0 |
| 5 weeks after third dose | — | 3 | 2 | 9 | 3 | 7 | 2 | 92.5 |
| 12 weeks after third dose‡ | 2 | 1 | 6 | 8 | 5 | 2 | 1 | 88.0 |
| 16 weeks after third dose‡ | 3 | — | 9 | 5 | 5 | 3 | — | 88.0 |
| 40 weeks after third dose‡ | 3 | 5 | 6 | 6 | 2 | 2 | 1 | 68.0 |

* 27 subjects remaining.
† 26 subjects remaining.
‡ 25 subjects remaining.

is not uniform. If we assume that 0.1 unit of antitoxin per ml. of serum is the minimum satisfactory level, we find that 87 per cent of this group show titers in the "protective range."

It is the antibody response to the administration of the trivalent mixture containing the toxoids for *Clostridium perfringens, oedematiens,* and *septicum* that probably interests us chiefly. Most of the evidence indicates that the three antigens do not interfere with the response elicited by the individual antigens.

In this paper, no attempt has been made to present a critical evaluation of these antigens. A small portion of the data obtained by the various groups of workers is presented to give a general picture of what can be expected from their administration.

It is difficult to summarize the present status of the immunizing

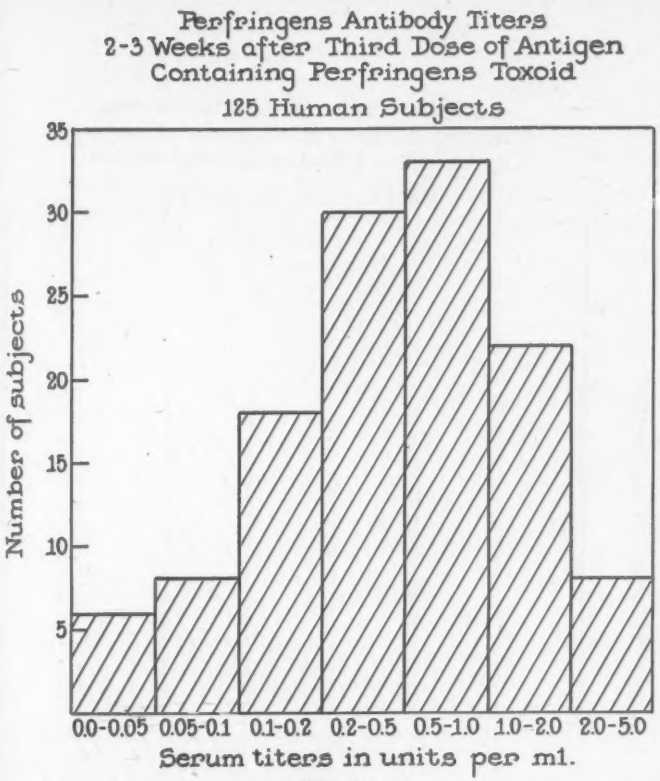


FIGURE 1.

agents against gas gangrene as related to man. We know, by the administration of these toxoids, that we can protect a series of species of animals against live cultures as well as toxin challenges. These animals include mice, guinea pigs, rabbits, pigeons, and dogs. We know that human subjects respond to these antigens with the production of serum antibodies at levels comparable to those found in protected animals. We believe that there is every prospect that these antigens, administered in three doses, properly spaced, will protect human subjects against a field infection of these three organisms, *Clostridium perfringens, Cl. oedematiens,* and *Cl. septicum.*

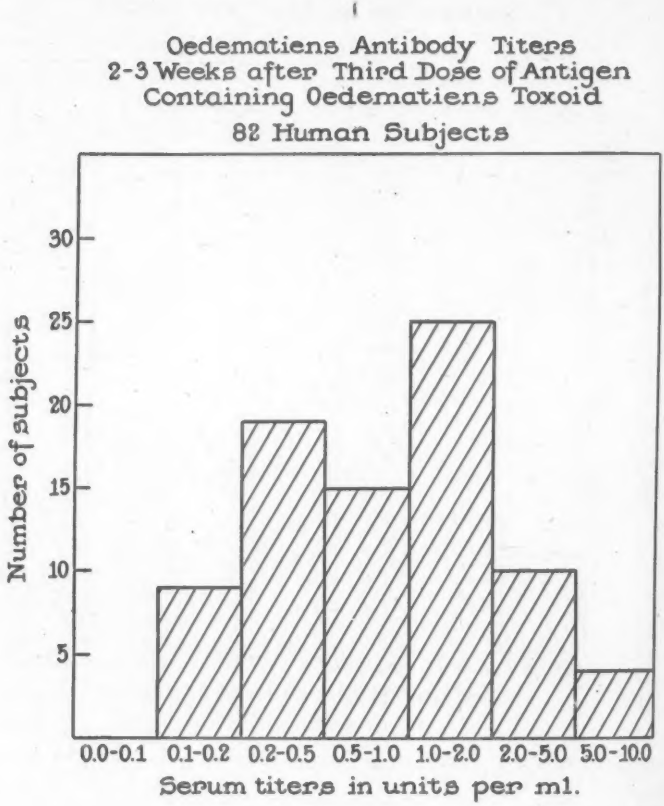
Oedematiens Antibody Titers
2-3 Weeks after Third Dose of Antigen
Containing Oedematiens Toxoid
82 Human Subjects
Number of subjects
30
25
20
15
10
5
0.0-0.1
0.1-0.2
0.2-0.5
0.5-1.0
1.0-2.0
2.0-5.0
5.0-10.0
Serum titers in units per ml.

FIGURE 2.

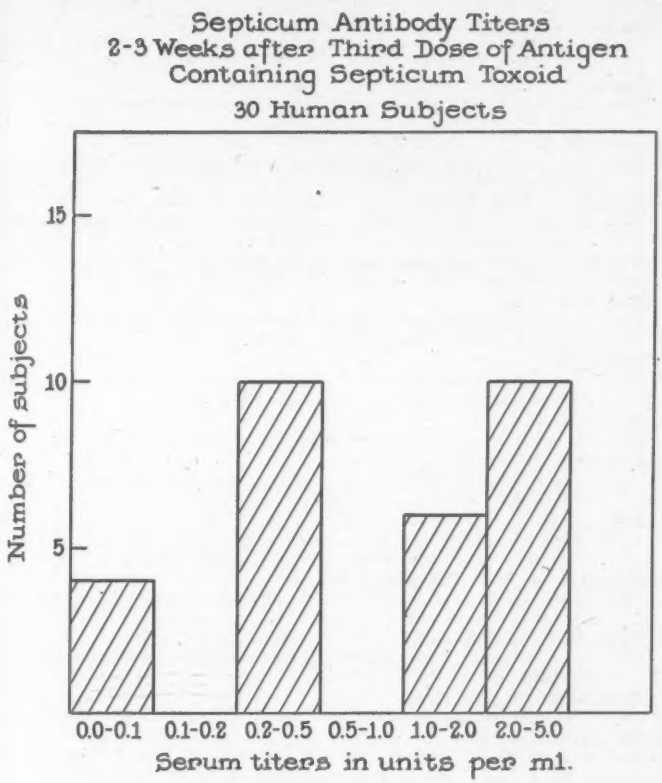


FIGURE 3.

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## SECTION OF PSYCHOLOGY

### MAY 23, 1947

DOCTOR WILLIAM H. SHELDON, Presbyterian Hospital, New York, N.Y.:: *A Constitutional Approach to Psychiatric Classification.* (This lecture was illustrated by lantern slides.)

(This paper will be published in Volume 10 of TRANSACTIONS.)

## SECTION OF ANTHROPOLOGY

### MAY 26, 1947

DOCTOR PAUL S. WINGERT, Department of Fine Arts and Archaeology, Columbia University, New York, N.Y.: *Congo Art.* (This lecture was illustrated by lantern slides.)

Before the European explorations of the past seventy-five years had disrupted the old patterns of life, the southern portion of the Congo basin was one of the richest art-producing areas of native Africa. This vast region, extending from the Atlantic Ocean to the great lakes, includes the land along the Congo River and that of its southern tributaries. Almost entirely within the present limits of the Belgian Congo, it is inhabited by many tribes who speak a variety of dialects of one linguistic stock, the Bantu. In the past, the economy was largely agricultural, while politically most of the tribes were organized under a paramount chief, sub-chiefs, and nobles. A great diversity of cultures developed in this area, but there was, throughout the Congo, a considerable diffusion of certain cultural elements, such as initiation rites, fetishism, the poison ordeal, and types of art objects.

The physical environment consists of heavy forests, especially along the main courses of the rivers, and comparatively open forests and grasslands. With few exceptions, the rivers flow north, emptying into the Congo, and divide the land into a number of parallel north-south compartments. However, neither the forests nor the rivers create insurmountable barriers to communication. A very considerable shifting and movement of peoples have, in fact, characterized the entire Congo basin. This was largely caused by invasions from the north, south, and east, and by inter-tribal wars. There were also widespread trade contacts. It is not surprising, therefore, that a number of cultural elements were common to many tribes.

Congo art includes sculpture, weaving, pottery, metal work, and some painting and basketry. Of these, sculpture is by far the most important, as it is for all of native Africa. Wood was the material generally used, with ivory preferred in some regions. The carvings were always small, few more than two feet and many less than six inches high. The greater number have the human figure as subject matter,

carved, with few exceptions, in the round. An almost equally common art form is the mask for which human features are the basic motivation. Animal forms are surprisingly rare in Congo art and are chiefly found in the rich vocabulary of decorative motives developed by some tribes. In this decorative art, human as well as animal forms often combine with geometric motives based usually on weaving patterns. Color is used extensively on masks, but other carvings are painted in black, red, or white monochrome. The total effect of a work sometimes depends on a variety of other materials that are attached to it, such as, for example, shredded raphia, clay, shells, beads, ivory, metal, feathers, or even pieces of leather.

The Congo sculptor was, in most cases, a professional craftsman who had served an apprenticeship. Sometimes, he was also a fetisher, sorcerer, or priest. He worked without models, although within the tradition of his tribe, and in some areas used a special long-handled knife that fitted into the bend of his elbow. The sculptor was practically everywhere esteemed socially, and among the Bushongo he was also politically important, holding the highest rank of the craft representatives on the king's council. The position of the sculptor in his society and the demands placed upon his services reflect, in general, the comparative economic security of Congo peoples which allowed the leisure necessary for the creation and enjoyment of art.

The greatest amount of sculpture was required for religious purposes. Two religious concepts, those of animism and of ancestor worship, neither of which was mutually exclusive, prevailed throughout the Congo. The sculptor was, therefore, called upon to carve fetish and ancestor figures. In either capacity, the carved figure never represented a god and was never worshipped; rather, it served as an intermediary through which a specific spirit could be contacted. In some areas, ancestor figures were carved in memory of the dead and seem to have had no religious significance. Elsewhere, offerings and petitions were made to these carvings in the belief that the spirit of the ancestor would come to the aid of the living.

Fetish figures, if not carved by the fetisher, were turned over to him by the sculptor so that he might add the necessary magical substances without which they had no meaning and served no purpose. In many cases, cavities were provided in the carving, either in the top of the head or in the front of the abdomen, for the insertion of these magical substances, although in some areas they were merely added to

the surface of the figure. Once they were added, it was believed that the carving had a soul and, when properly petitioned, usually through the intervention of the fetisher, would act as an intermediary to specific spirits in an effort to attain the desired results.

Fetish figures were seldom carved with the same care as ancestor figures and were, with certain exceptions, usually smaller in size. Some of them were set up in their own huts and were the property of the community, each with its own fetisher who knew the prescribed method of activating the power of the fetish. Others were the personal property of the fetisher, and some belonged to other individuals. In many regions, small figures, when properly treated by the fetisher or by the sorcerer, were carried, worn, or handled as charms to ward off evil or to bring good fortune.

An important type of Congo sculpture is represented by the mendicant figure which depicts a kneeling or seated female holding a bowl. Measuring less than two feet in height, these carvings were carefully made and were put to different uses with apparently different meanings attached to them. Some were carved in honor of a respected mendicant spirit and, when these were placed by their owner, at times, in front of his house, persons passing by would drop shells or other objects of value into the bowl, in honor of the spirit. The procedure, thus, seems to have been a way of asking alms.

A mendicant figure was also placed outside the hut of a woman during the period of childbirth, when the equivalent of money was again dropped into the bowl by persons passing by. In this way, the household would be compensated for the loss of the services of the woman during this period. It seems that the carving, in this instance, was a commemoration of the nobility of motherhood or a symbol of that respected state. There is also some possibility that this type of mendicant figure may have been, at one time, related to ancestor worship when the figure would have symbolized the revered mothers among the ancestors of the tribe.

Somewhat similar to the mendicant figures are a series of divination bowls. Two seated figures, a male and a female, are carved at either side of a bowl which they are represented as supporting between them, their legs encircling the base and their arms the brim. The figures are cut from the same block of wood as the bowl of which they form an inseparable part. Since these were ritual objects, it is likely

that the two figures represented specific spirits who, it was believed, aided the divination rites.

A great variety of masks were used in the Congo for religious, social, or political purposes. They were worn during initiation ceremonies, when a youth was admitted into the adult society of his tribe; as part of the circumcision rites which sometimes preceded or replaced the former; and by members of secret societies. In some few cases, masks seem to have been set up and used in place of fetish figures. They were also used in funerary rites and, in this role, were probably associated with ancestor worship.

There were three principal types of masks: the helmet type which fitted either partially or entirely over the head and rested on the shoulders of the wearer; the face mask that was worn over the face; and a type made with a handle by which it was carried and held before the face. More or less complete costumes of raffia and a variety of other materials were usually worn with the masks, since the identity of the wearer had to be concealed as completely as possible. The masked person in many instances became, during the time he was using the mask, the incarnation of the spirit or of the ancestral or mythological being which the mask represented or symbolized, and his conduct was prescribed accordingly. In theory, women and uninitiated males held to this belief, especially with regard to secret society and initiation masks which were often worn to keep them away from the rites. Some masks could not be seen, under penalty of death, by any one who was not a member of the society. Others were worn publicly when all members of the group participated in or witnessed the dances. But the actual meaning and use of many masks have never been divulged and will never be known, since they are no longer used and this knowledge is fast disappearing.

Congo decorative sculpture can be divided into two categories, *viz.*, that in which the human figure in the round was used, and that in which representational and geometric designs were carved in relief on a surface. Neck-rests and stools were used generally as objects of utility, the neck-rests averaging six inches and the stools two feet in height. In many areas, the human figure, usually a female, was used on both of these objects in a distinctive functional and decorative manner. The stem of the neck-rest or stool consists of a standing, kneeling, or seated figure resting on a circular base and supporting on its head the circular seat of the stool or the curved top of the neck-rest.

Frequently, the arms are held so that the hands of the figure furnish additional support for the top. These caryatid-like figures are often so successfully designed that they do not appear to be overburdened with the weight that they structurally support. Carved stools and neck-rests were made for the chief or nobles of a tribe. Although some of them were used ceremonially, they do not seem to have had any significance but were largely prestige objects.

Both categories of decorative carving are found on the wooden cups used extensively in the central and western Congo. The shapes and decoration of these cups are extremely varied. Some are carved as human figures and support on their head the body of the cup or have their head hollowed out as such. Others are shaped as a human head in the round, with the body of the cup hollowed out within. Still others have a human head or a complete human figure carved in high relief on the surface. A large group of cups, however, are decorated with geometric designs derived from weaving patterns.

Cups average about six inches in height and were often carefully carved of very hard wood and given a high polish. Some of them were made specifically to be used in the poison ordeal, while many others were merely intended to be used for drinking palm wine or as objects of display. Carved cups were also utilized to hold tukula powder. This was obtained by powdering a reddish wood and was believed to have certain magic properties, although it was also used as a cosmetic. It had a very wide distribution throughout the Congo and was used as a pigment. Many carved figures were rubbed with it, and it was used extensively for ceremonial body painting. The carved wooden cups have been too closely identified with the Bushongo (Bakuba) tribes of the inner Congo, whereas they had a fairly wide distribution and can be recognized, on stylistic grounds alone, as the work of many other tribes.

A number of other objects were carved decoratively in the Congo. Knife handles, for example, were frequently carved with human figures or heads in the round or with geometric designs; scepters, used ritualistically, were also often decorated with human figures; and in the central and eastern areas some of the finest sculpture appears on bow-rests, where a human figure, usually a female, was carved in the round as a support for the pronged rest for the bow. The majority of carvings of this sort were prestige objects. It is, therefore, apparent that there was a considerable amount of *l'art pour l'art* in the Congo

area. Perhaps, originally, some of these sculptures had religious significance, but by the time of European contact they had become basically art objects in their own right.

Style, in a work of sculpture, is the sum total of a number of factors, such as the proportioning of parts, the shaping of these parts, the design or arrangement of them to establish certain relationships, the concept of form as volume or mass, the treatment of surfaces, and the rendering of detail. A great many sculptural styles were developed in the Congo basin. Some differ only slightly from one another in design and detail, and many have substantially the same basic principles. It is possible, however, to distinguish a certain number of major style traditions. Eight of these are clearly recognizable. They are: the *Bakongo-Mayombe,* of the lower Congo River; the *Bateke,* slightly to the northeast; the *Bayaka-Bapende,* to the southeast between the Kwango and Kasai Rivers; the *Bushongo,* in the central Congo area along the Sankuru and Kasai Rivers; the *Bena Lulua,* to the south of the Bushongo; the *Basonge,* to the east of the latter along the Lomami River; the *Baluba-Warua,* in the southeast and eastern parts of the Congo basin; and the *Warega,* in the northeastern part, east of the Lualaba River and northwest of the northern end of Lake Tanganyika. These eight styles embody the distinctive essentials of Congo art—the principles that determined its character, its aesthetic qualities, and its expression of African life.

The Bakongo-Mayombe style appears most clearly in a varied group of commemorative ancestor and fetish figures. Commemorative figures are represented as kneeling or seated tailor-fashion on a plinth. They were made to honor both male and female ancestors, the female figure usually holding a child on her lap or sometimes to her breast. The proportions are often more nearly naturalistic than is usual in African sculpture. Arms and legs are full-volumed, the torso rather attentuated, and the head large and impressive. The expressiveness of these carvings, however, does not derive from the head alone, but from the figure as a whole. Descriptive details, such as scarification designs, bracelets, armlets, and often the inclusion of carved finger nails, are carefully rendered. Distinctive of this style is the openness of the design. The forms are carved free and in the round, and emphasize structural and rhythmic relationships. The figures are posed in an attitude of homage or respect; the torso and neck inclined slightly forward and the large head tilted backward. The heads of Bakongo-

Mayombe carvings are nearly round, the faces very wide, and the features large. The ovals of the eyes are widely spaced, the noses slightly short, and the mouths, often half-open to show the filed teeth, are enormous and are generally half-circular in shape, the lower lip straight and the upper widely curved. Shell or glass inlay frequently appears in the eyes, although the eyes are sometimes carved, the upper lid drawn down as though they were half-closed. These figures produce an effect of monumentality and a tenseness of expression which the vigor of the forms and the pose give to the calmness of the features. Commemorative figures were revered but not worshipped. They were preserved in the huts of descendants and, in recent times, have actually been placed on the tomb of the deceased.

Fetish figures in this style are less carefully carved. The proportions are heavier and more attention is paid to the large head, since the body was intended to receive magical materials or nails and pieces of metal which were inserted to call the attention of the spirit to the petitions directed to it. The concept of organic structure and the pose of the torso and head, however, have the basic style characteristics of the commemorative figures and indicate that both groups embody the same tradition.

Very small fetishes, averaging about eight inches in height, are typical of the Bateke style. These are full-length standing figures, usually asexual. They are very compact in design, the arms never cut free of the body, and the pose stiff and frontal. In proportions, they differ sharply from those of the Bakongo-Mayombe style. The legs are short, heavy, and flexed; the torso is long and columnar; and the very large head and the long spool-like neck are, together, nearly as long as the torso. The parts of the body, clearly marked off from one another, have a geometric stylization and are not conceived as volumes in space but rather as a spatial linear pattern. By far the greatest attention is devoted to the head, the torso being often covered with a large globular mass of magic material. The head is long and narrow; the coiffure variable, sometimes crested, sometimes a flat, cap-like form; the forehead rounded and protruding; and the facial features composed of narrow sharp-pointed eyes set close together, a short rather flat nose, a large open oval mouth carved in high relief, and a square-shape short beard. Distinctive scarification marks, usually found on these figures, consist of fine parallel vertical incisions cut on the cheeks from the eyes to the jaws. Aside from these, there are sel-

dom any other descriptive details. The technique is usually rough but vigorous, knife marks often remaining and giving a textural quality to the surfaces. Angular rhythms, the expression of the downward press of the weight of the forms, and the impressive detachment of the large heads are characteristic of this style.

These fetishes represent one of the distinctive sculptural traditions of the Congo. The Bateke were traders who migrated from the southeast and possibly brought with them a developed fetishism. Their influence was widespread over a large area of the western Congo, where various sub-styles were based on theirs.

The fetish figures of the Bayaka tribe of the Bayaka-Bapende style resemble in their design, proportions, and surface treatment those of the Bateke. They are somewhat larger, however, and have a more dramatic angularity of design; but the greatest differences appear in the treatment of the head and facial features. The shape of the head is often not as long as that of the Bateke and is frequently topped by a crest-like coiffure. Facial features are very large and are spread out over the entire surface of the face below the rounded forehead. These are peculiar to the Bayaka style. Large tab-like ears project at right angles at the sides of the head; very large eyes are shaped like cowrie shells and carved in high relief; a long nose with a depressed bridge often terminates in an enormous curved end; and an open oval mouth, usually with teeth showing, is carved at the very end of the face, frequently with little or no chin beneath. Also typical of this style is the continuation of the hair-line around the sides of the face to the nostrils as a rim-like relief carving. Some of the figures are asexual, but many of them are male or female. As compared with the Bateke figures, they are aggressive and dynamic in expression. Many of them are roughly carved, and they do not have any descriptive detail.

Some of the Bayaka figures are larger in size and were carved with greater care. They were probably commemorative ancestor figures. Some of them have a bird or animal form carved in the round on the top of the head in place of a coiffure, and it seems likely that these commemorated an ancestor who was a famous hunter, an occupation which was of great importance among the Bayaka. It was believed that the abundance of game depended upon the goodwill of the ancestors. Hence, figures of this type probably functioned as ancestor figures that were petitioned when game was scarce.

The Bayaka-Bapende style is also represented by a variety of

masks, the majority of which were used in circumcision and initiation rites. Distinctive of the Bayaka tribe is a composite type. The lower portion was carved out of a block of soft wood, the features of the face deeply recessed within an encircling frame. These facial features were often identical with those of the carved figures, but in many the nose was so grossly exaggerated that the end forms a great hook or loop. The eyes, also, sometimes differ slightly from those of the figures and are represented as closed, a narrow slit separating the upper from the lower lid and providing an aperture through which the dancer using the mask could see.

The mask was not worn, but was held in front of the face by a handle which was carved below the chin. To the top of the mask a variety of shapes were attached, some representing figures, some animals, and others huts and abstract forms, built up out of bamboo, raffia, and clay. These referred to specific mythological and ancestral figures or events and were of instructional value for the novice. Masks of this type were painted red, white and black, and are unique among African masks.

The Bayaka also used a helmet type of mask that was carved from a single piece of wood. It is large in size and is found in almost identical form among the neighboring Bapende. This type is without the characteristic Bayaka hook nose, the nose being flat and rather small. Eyes are shaped similarly to those of the composite Bayaka type. Surfaces are carved with great sensitivity for the expression of volume, and the features are cut lightly on the surface so as not to create an impression of heaviness. An animal or human figure is frequently carved in the round just above the forehead. The only important difference between the Bayaka and Bapende versions of this type of mask is the treatment of the mouth: in the Bayaka it is open, showing sharp filed teeth, while in the Bapende it is usually closed. The aggressive mouth of the Bayaka mask is in such contrast with the sensitive facial planes that a discordant note is struck. The Bapende helmet masks are without this discord and have an expression of almost delicate sensitivity, but it is found in the skull-like Bapende circumcision masks and in some of the finely carved ivory mask-like charms.

It would appear, therefore, that the styles of the Bayaka and the Bapende tribes represent such a complete fusion of elements that the two actually belong to a single basic tradition. Perhaps the more dramatic and aggressive elements came originally from the Bayaka, and

the sensitivity of form and expression from the Bapende. The only individual style characteristics which seem to have been retained by these two tribes are the huge hooked nose of the Bayaka and the diamond shape of some of the Bapende masks. The Bayaka-Bapende tradition exerted considerable influence on the art of the tribes living around them, and certain minor styles varying slightly from it can be perceived.

Perhaps the best known pieces of sculpture from the Congo are the royal portrait statues of the Bushongo kings. These constitute one of the few groups of African carvings to which an approximate date can be attached. Tradition states that Shamba Bolongongo, the 93rd king (*nyimi*), who was somewhat of a culture hero, brought to his people as a result of his extensive travels in the west the art of weaving. He also had his portrait carved so that the people could, in later years, be cheered by it in times of adversity. This seems to have established a precedent that was followed by other kings.

The genealogy of Bushongo kings names 121 rulers, and it is recorded that during the reign of the 98th king there was a total eclipse of the sun, an event which has made it possible to fix the date of 1680 as belonging to that reign. The approximate date of 1600 can, therefore, be assigned to the reign of Shamba Bolongongo. It is believed that thirteen royal Bushongo portrait statues have survived, seven of which have been identified with some degree of certainty, and six tentatively.

In pose, these sculptures recall the Bakongo-Mayombe commemorative ancestor figures. Like them, they are seated tailor-fashion on a plinth. They wear the curious flat board-like crown of the Bushongo kings, as well as the appropriate articles of decoration, such as cowrie shell belt and armlets, and metal bracelets, shoulder and neck rings. In the left hand a short sword, an insignia of office, is held, and in front of the state is carved some figure or object to symbolize an important event that occurred or a contribution that was made by the king during his reign. The proportions are far heavier than those of the Bakongo-Mayombe figures, the pose more static, and the design more compact. The forms, less generalized than those of the western figures and even more naturalistic, are so ample in scale and so compactly knit together that these Bushongo carvings give an impression of heaviness. The largeness of the torso, the shortness of the neck, and the massive head contribute considerably to this effect. The head

from the chin to the crown is egg-shaped, but it is wide at the forehead and brows. The features of the face are carved in high relief and do not disturb the volume of the head. They are large, widely spaced, the eyes half-closed similarly to those of the Bayaka-Bapende masks, eyebrows clearly carved, the nose large and fleshy, and the mouth represented as closed and full-lipped.

These Bushongo sculptures are generic portraits of African divine kingship, expressing aloofness, severity, and strength. They show, individually, slight modifications in proportion and in detail to bring the type into some relationship with the peculiarities of the king represented. They are carved in very hard wood, the surface carefully finished and given a high polish. Few African works are as descriptive, as individualized as these figures, and few express more successfully the timeless composure, the grandeur of carved shapes, and the monumentality of related masses.

The likelihood that Shamba Bolongongo conceived the idea and the pose for these figures during his travels in the west suggests that it came from the Bakongo-Mayombe tradition. Similarly, the great number of carved wooden cups from the central Congo region raises the question of whether the Bushongo might not, also, have acquired this type of carving from the west, since the style of many of them is in the Bayaka-Bapende tradition. It must be remembered that the Bushongo were a confederation of a number of tribes that spread out over a large area of the central Congo. Many of them certainly had trade relations with their neighbors and the diffusion of elements must have been considerable and must have worked both ways. Many of the cups, both the so-called portrait cups and the geometrically decorated ones, have obvious Bushongo style features. They are carefully carved in a very hard wood, highly polished, and in a relief technique. Boxes of a variety of shapes were similarly decorated in the central Congo. By the richness of their motives, the boldness of their designs, and the magnificence of their technique, these carved cups and boxes represent the finest examples of African decorative sculpture.

The types of masks used by the Bushongo were, according to tradition, borrowed from their neighbors. These were large, polychromed, and very dramatic in design. The most characteristic was that used by the Babende Secret Society. It was made of wood or bark, the surface richly painted in small geometric designs suggestive of weaving patterns and profusely decorated with cowrie shells and beads, a con-

tinuous strip of them being placed from the bridge of the nose down to the point of the chin. A more dramatic type of mask is that known as the "Bombo." It was worn during initiation rites, which was a borrowed trait among the Bushongo, and consisted of a sharply protruding rounded forehead, a narrow face, and prognathous chin, the whole surface elaborately painted in parallel design elements. It was said to have been based on the skulls of the Pygmies and was worn to frighten women and uninitiated away from the initiation rites. The Pygmies figured prominently in Bushongo myth and legend as terrorizing beings, which had a basis in historic fact, since the Pygmies with their poison arrows were invisible instruments of destruction with which the Bushongo in the early days of their migration into the central Congo area could not cope. The "Bombo" mask, however, is closely like that of other tribes to the south and southeast and must certainly have been a borrowed form.

The influence of Bushongo style in the central Congo was very great. This is evident in a number of sub-styles in that area, but it should be kept in mind that the basic types and forms of this style were derivative and were refined and enriched by the superior craftsmanship of the Bushongo who gave to these borrowed elements a distinctive character.

The Bena Lulua, who were a tribe of Baluba origin and originally came from the south-southeast, also developed an important major sculptural style in the central Congo area. This style differs remarkably from that of the Bushongo. Characteristic of Bena Lulua carving are a group of standing male and female figures, many of them only six inches high. Their proportions are slender and elongated, consisting of short, heavy legs, long slim torso, very long neck, and a large distinctly shaped head, usually with a crested headdress. The forms are roughly shaped and are more important as surfaces to decorate than as carved shapes. An outstanding feature of Bena Lulua style is the carving, usually in low relief, of an elaborate curvilinear facial scarification. Concentric circles were used as stylizations of shoulder, elbow, and knee joints, and many of the figures have an elaborately decorated neck, the carving sometimes suggesting a beaded collar, sometimes a scarification design. The shape of the head is unique among African figures. Rather long and broad, it has a wide, almost bulbous cranium. Of the facial features, the most noteworthy are the huge eyes, carved with a very large half-closed upper lid. The male

figures have, in most cases, a short elaborately braided beard divided into three strands. It is essentially an elaborate, decorative style, the figures seeming to have little weight or mass.

The function and meaning of these sculptures are debatable points. They have been considered by some as fetishes, by others as charms; while still others have pointed out that the absence of magical materials would seem to suggest that they are commemorative ancestor figures. Some of the larger male figures, clothed in leopard skins and carrying the insignia of chieftaincy, and some of the female figures carrying children are, in all likelihood, ancestor figures. But the majority of these carvings were rubbed with the reddish tukula powder, which had magical implications if not powers, and it seems probable that some of them were fetishes. Both fetishism and ancestor worship existed among the Bena Lulua.

Masks of the Bena Lulua are dramatic, colorful, and unrelated to their figure style. They are of the same general type as the "Bombo" mask of the Bushongo, who, tradition states, acquired masks from the Bena Lulua. What little is known of their meaning and use suggests that they were also similarly used. The influences of the figure style of the Bena Lulua appear in a number of sub-styles in the south central Congo area, while there are certain stylistic ties between it and the major styles to the east and southeast.

Also of Baluba origin, the Basonge tribe to the east of the central Congo developed a style which only in minor elements has any kinship with other styles of this area. A number of small standing fetish figures show its typical elements. Proportions are short and heavy; the forms solid and carefully carved; and the legs sharply flexed, giving an angular rhythm to the figures. The heads are very large, round, almost squarish in shape, with a wide rounded cranium suggesting somewhat the Bena Lulua type. Eyes are large, widely spaced, and sometimes inlayed with shell or metal. The mouth, perhaps the most characteristic feature of this style, is open, but pinched together in the center, forming a horizontal figure-eight design and producing a grimacing effect. The neck is often very long, recalling a like feature of Bena Lulua style, and is sometimes carved with a number of widely spread concentric rings. There are no scarification marks on these figures, but pieces of metal or shell are often inlayed in small squares on the torso. In the top of the head, there is a cavity made to receive either a small horn or a carved wooden horn into which magical substances

were inserted before it was set in place. Basonge fetishes were carved by fetishers, some of whom were more skilled than others; hence, the rather uneven quality found in figures of this style. All of them, however, have an aggressive, menacing expression to which the angular rhythms and the massiveness of the forms contribute.

The Baluba-Warua style in the eastern and southern area is one of the most genuinely sculptural and the most satisfying aesthetically of the entire Congo basin. Three types of carvings best represent this style: standing ancestor figures, stools carved with human supporting figures, and mendicant figures holding a bowl. In reality, this tradition consists of two styles, both of which are based on the same principles but differ in minor respects. These are the Baluba of the Manyema district, west and south of Lake Tanganyika, and the Warua to the west of the central shore of that lake. The sculptures of both the Baluba and the Warua are characterized by a calm serenity of expression, a sensitivity in the flow of surface planes, a refined technique, and a feeling for finely carved shapes.

Standing female ancestor figures are the finest examples of the Warua style. These are posed in a balanced, completely frontal manner, the arms flexed and resting on and holding down the breasts. In proportions, they recall somewhat those of the Bena Lulua style, building up from short, sturdy legs to elongated torsos to large heads. However, the forms here are carefully shaped and express volume and weight. They differ also in their character. The torso is a slender volume so shaped that it seems to fit down between the hips; the breasts are small but full and pendulous volumes; the navel protrudes; and the lower part of the abdomen is profusely decorated with an elaborate geometric scarification design. The shoulders are rather wide, rounded, and slightly drawn up. The neck is a moderately short, finely shaped cylinder; while the head frontally is an almost complete circle, which has considerable depth to the back. The hair-line above the domed forehead is high and is marked by a ring of vertical parallel incisions; above that, the characteristic Baluba coiffure, found also among the Warua, develops to the back where the hair is drawn in a cross-pattern over a bamboo framework. The facial features are placed low, the widely spaced eyes carved with closed and hooded upper lids, the nose full and flat, and the mouth with thin, closed, protruding lips. A very short chin appears below the mouth. Large, well shaped, flat ears are carved to either side of the head, which consists

of a rhythmic pattern of elegant curvilinear forms. Surface planes flow into one another with great refinement, allowing full expression to sensitive oval shapes. Body forms are interpreted as a play and balance of cylindrical shapes, the sturdy legs supporting the heavy torso to which are affixed the slender volumes of the arms and the neck, which, in turn, supports the volume of the head. In the design, there is a fluidity of line and a flow of carefully balanced volumes. The finest examples of these figures are among the great masterpieces of African sculpture. Similar carvings are used as supports for bow-rests, and, with certain adjustments, as supporting carvings for neck-rests and stools, and as mendicant figures.

The mendicant and stool figures of the Baluba (Manyema) have slender, almost emaciated, proportions, long narrow heads, and emphasize an expressive structure rather than volume. The flow of line-pattern and volume is missing from these figures. Cheekbones, bridge of the nose, and the bony character of the forehead are stressed by the modelling of the carved surface so that it catches and utilizes the possibility of light and shade effects. The shaping of facial features, nevertheless, especially the eyes, and the basic importance of rhythmically spaced oval shapes in their design are very similar to those found in the Warua figures. The calmness of the Warua figures, however, gives way here to an almost nostalgic sadness, though the expression in both cases is conveyed with a similar degree of sensitivity.

One of the most spectacular types of Congo masks, the Kifwebe, represents another facet of Baluba style. It was also used by the Basonge and, in a modified form, by the Bena Lulua. The actual design of the mask varies considerably from a completely oval to a long narrow diamond shape, while the features are also variable and are either carved on the surface or project from it. In every case, however, the surface is carved with a series of curvilinear or rectilinear parallel lines. These are painted alternately white and black. The masks are usually large and the design makes them appear even larger. They were used in funerary rites and in dances when important visitors were present. It seems that their significance must originally have been far greater. Their exact meaning and original purpose have probably been completely lost.

Baluba-Warua style exerted a very wide influence. The Warega style to the northeast, in fact, is but a more staccato and less skilful rendering of the basic principles of this style. The sensitivity, the re-

fined expressiveness of the Baluba-Warua is replaced by broken volumes and line patterns, by segregated shapes, and by an attempt to use the principles which gave to that style its quality, but without an understanding of those principles and without the technical ability to achieve subtle effects.

Warega style is nevertheless important. It developed under the combined influences of two radically different traditions, namely, the Baluba-Warua of the eastern and southern Congo and the less technologically advanced sculptural styles of the great lakes area to the east of the Congo. The finest examples of Warega style appear in their ivory carvings, such as masks and small neck-rests. The harder, more resistant material seems to have exercised a certain control which is manifested in the stronger and more simplified planes and in the lack of surface detail. Forms also achieve in ivory a more structural character, a greater expression of mass. It is possible that ivory carving was an old medium among the Warega and that wood carving was of fairly recent development, a new and borrowed medium.

The major sculptural styles of the Congo can, therefore, be fairly clearly identified. These styles can be localized, relationships between them established, and possible points of origin of some of them suggested. The Bakongo-Mayombe, for example, seems to have absorbed no outside influences in the development of its commemorative figures, but it seems just as likely that certain alien influences, probably from the Bateke or from the southeast, lay behind the development of its fetish figures. The commemorative figures appear to be the older of the two and represent the finest examples of this style. The Bateke style appears to have been a foreign infiltration from the southeast. It seems to have been uninfluenced to any extent by outside sources, although the developed technique found in some of the finer examples of this style may be due to extra-tribal contacts. On the other hand, the Bayaka-Bapende style, which also seems to have been of southeastern origin, appears to have absorbed certain minor influences from the Bakongo-Mayombe and from the Bateke. But it exerted a far greater influence than it absorbed, possibly because of the aggressive character of its culture. The Bushongo style, however, is in many respects almost eclectic. These peoples came from the northwest. Their migrations were prolonged and brought them into contact with a great variety of cultures. They therefore probably became accustomed to adopting as their own certain elements of the cultures with which they

came into contact. It is apparent that a number of strains are fused to form the Bushongo style. Influences from the Bakongo-Mayombe appear in the royal portrait figures, while the strongest style elements in their masks came from the east and southeast. Bena Lulua style represents a basic tradition that seems to have come originally from the south and southeast. All of their stylistic affinities seem to lie in those directions. The Basonge tradition indicates a development under influences from the same direction, although the aggressive character of this style suggests other influences from the west and south. The Baluba-Warua style appears to have been, like the Bakongo-Mayombe, little affected by outside contacts. The style seems to have developed in the southeastern area of the Congo and exerted rather than absorbed influences. The Warega, on the other hand, is an eastern and northern extension of the Baluba-Warua style, and shows clearly an adaptation of that style under strong eastern influences. Minor styles can, in most instances, be associated with one or more of these major styles. In them, a deficiency of technique and the lack of the ability to assimilate the elements of the major styles with which they came into contact led to a poorly developed and comparatively meager sculpture.

Certain common characteristics may be discerned in all Congo sculpture. With few exceptions, the pose of the figures and their forms resulted from two almost equally important factors, namely, the tradition in which the sculptor worked, and his powers of perception of the life about him. That life was never represented realistically but was interpreted and expressed within the tribal tradition and the bounds of the medium of wood carving. For these purposes, the significant was emphasized, often amplified or further distorted, and the unimportant was either generalized or entirely suppressed. The concept was therefore creative and was not restricted by the limitations of realism—there was no concern with making an object in one material (wood) look like an object in another (flesh and bone). Each work, consequently, had its complete existence as a work of sculpture, not as a representation or simulation of nature. Each work also had a complete integrity of purpose—it was made with a specific meaning to serve a specific purpose, and that purpose was seldom individual but was one shared in common by all members of the group. The work, therefore, becomes expressive of the culture of the group as a whole, and not the expression of an individual within the group. The carving

was, thus, understood by every one of the tribe and it or an object similar to it was used by most members of the tribe.

Nevertheless, the individual ability and sensitivity of the sculptor counted for as much in Congo sculpture as it has in sculpture of all countries and ages. This is evident in the recognition that some objects are far superior in quality and expressiveness to others: they are masterpieces. The range of quality, however, seems to have been generally high, higher certainly in some tribes than in others. A sureness pervades the work of the Congo sculptor, with but comparatively little evidence of virtuosity. A control, a restraint mark the finest examples and give evidence of that sureness—nothing appears to be there that should not be, and nothing could be added. The work is complete in itself. It has its own existence in space and its aesthetic qualities are purely sculptural.

## SECTION OF PHYSICS AND CHEMISTRY

### MAY 23, 1947

DOCTOR I. FANKUCHEN, Department of Chemistry, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.: *X-Ray Diffraction and Colloidal Aggregates.*

Ten years ago, the measurement of dimensions of colloidal particles and the study of the arrangement of such particles was difficult because the distances involved fell in an awkward range. The standard techniques of x-ray diffraction were useful for measuring distances from atomic dimensions up to about 50 A. U., and microscopy using ultraviolet light had gone down to the order of 1000 A. U. The gap between was just that region in which the interesting colloidal phenomena occurred. Today, x-ray methods have reached up to 500 A. U., and the electron microscope has a resolving power of 10–15 A. U. The gap is closed.

X-ray scattering can give information concerning the structure and dimensions of colloidal particles and of their states of aggregation. Aggregates of colloidal particles can have periodicities in their arrangement which are three-dimensional (crystalline proteins), two-dimensional (some virus proteins), one-dimensional (collagen), and zero-dimensional (carbon black).

The x-ray scattering reflects the nature of the periodicity. Protein crystals are true crystals, and save for the angles of scattering which are small, the patterns are similar to those given by crystals of small molecules. To obtain such patterns, only refinements of existing techniques are necessary; indeed, where any type of periodicity (save zero) is present, the x-ray scattering will show maxima at angles which can be correlated with the magnitude of the periodicity.

X-ray scattering can also tell something about the dimensions of colloidal particles even when their mutual arrangement contains no periodicities. In this case, a continuous type of small angle scattering is obtained, whose angular variation is a function of the dimensions of the particles. Such continuous small angle scattering has been used to study alumina, silica, and gold sols. For the case of gold sols, the

electron microscope has confirmed the results of the analysis of the small angle scattering.

Actually, most colloidal dimensions now can be studied both by x-rays and the electron microscope. In the few cases where both techniques have so far been applied, the agreement has been encouragingly good.

## SPECIAL LECTURE

### MAY 6, 1947

DOCTOR ALBERT SZENT-GYÖRGYI, Director, The Institute of Biochemistry, University of Budapest, Budapest, Hungary: *The Chemistry and Chemical Mechanism of Muscular Contraction.* (This lecture was illustrated by lantern slides.)

The contractile matter of muscle has been decomposed into two proteins, actin and myosin. The two proteins can be reunited to a complex which has the property of contractility. Contradiction is induced by a shift of electronic charges. These observations necessitate the application of a new theory of electronic structure of living matter, whose bearings on the functions of muscle are discussed.

(This paper is scheduled for publication in Volume 10 of TRANSACTIONS.)

## SECTION OF BIOLOGY

### MAY 2 AND 3, 1947

Conference on *"Structure in Relation to Cellular Function."*

The Section of Biology held a Conference on "Structure in Relation to Cellular Function." Doctor Robert Chambers, Laboratory for Cellular Physiology, New York University, Washington Square College of Arts and Science, New York, N. Y., was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

#### FRIDAY, MAY 2

*Morning Session.* "Some Features of the Physical Properties of the Living Cell," by Robert Chambers, New York University, Washington Square College, New York, N. Y.

*Cellular Surfaces*

"The Surface of the Erythrocyte," by M. H. Jacobs, University of Pennsylvania, Philadelphia, Pennsylvania.

"Optical Properties of the Cell Surface," by David F. Waugh, Massachusetts Institute of Technology, Cambridge, Massachusetts.

*Afternoon Session: Protoplasmic Structure*

"Studies on Cell Morphology and Functions: Methods and Results," by Albert Claude, Rockefeller Institute for Medical Research, New York, N. Y.

"The Localization and Role of Ribose Nucleic Acid in the Cell," by Jean Brachet, University of Pennsylvania, Philadelphia, Pennsylvania.

"The Surface Chemical Properties of Cytoplasmic Proteins," by M. J. Kopac, New York University, Washington Square College of Arts and Science, New York, N. Y.

#### SATURDAY, MAY 3

*Morning Session: Chromosomes and Nucleus*

"Salivary Gland Chromosomes," by Ethel Glancy D'Angelo, Queens College, Flushing, N. Y.

"Chromosomal Physiology in Relation to Nuclear Structure," by William R. Duryee, Carnegie Institution of Washington, Washington, D. C.

"Fiber Protein Structure in Chromosomes and Related Investigations on Protein Fibers," by Daniel Mazia, University of Missouri, Columbia, Missouri.

*Afternoon Session: Cytochemistry*

"Pitfalls in Histochemistry," by George Gomori, University of Chicago, Chicago, Illinois.

"Enzyme Systems of Isolated Cell Nuclei," by Alexander L. Dounce, University of Rochester, Rochester, N. Y.

"Function of Cell Inclusions in Metabolism of *Chaos chaos*," by Heinz Holter, Karlsberg Laboratories, Copenhagen, Denmark